Canadian Centre for Occupational Health and Safety

Centre canadien d'hygiène et de sécurité au travail

What Makes Chemicals Poisonous?

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WHAT MAKES CHEMICALS POISONOUS?

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1. WHAT ARE CHEMICALS?

Everything in the physical world around us is made of chemicals. The earth we walk on, the air we breathe, the food we eat, the cars we drive, and the houses we live in are all made of various chemicals. Living organisms such as plants, animals, and humans are also made of chemicals.

Some of the chemicals we contact in our daily lives are man-made. These include some drugs, cosmetics, workplace chemicals, household cleaning agents, and so on. Many more chemicals which we are exposed to each day occur naturally and are found in our food, in the air, and in water. There are far more natural chemicals in our environment than man-made ones. Both man-made and natural chemicals can have poisonous effects.

2. WHAT MAKES CHEMICALS POISONOUS?

There are several factors which can influence the degree of poisoning caused by a chemical. These are as follows:

- Route of entry into the body
- Amount or dose entering the body
- Toxicity of the chemical
- Removal from the body
- Biological variation

Route of Entry Into the Body

No chemical can cause poisonous effects without first coming into contact with the body.

Breathing of contaminated air is the most common way that workplace chemicals enter the body. Some chemicals, when contacted, can seep through the skin. Less commonly, workplace chemicals may be eaten if food or cigarettes are contaminated. The eyes may also be a route of entry. Usually, however, only very small quantities of chemicals in the workplace enter through the mouth or the eyes.

More details are given in the CCOHS publication, "How Workplace Chemicals Enter the Body."[1]

Amount or Dose Entering the Body

The amount or dose of a chemical entering the body is probably the single most important factor which determines whether a chemical will cause poisoning. The amount of a chemical which causes poisoning depends on the chemical. Consider, for example, what happens when water is drunk on a warm summer day. The water

cools the body and quenches the thirst. Normally, water would be classified as a harmless chemical, but if instead of just one glass, many glasses were consumed one after the other, non-stop, a point would be reached where beneficial effects would disappear and harmful effects would start to be noticed. Drinking too much water causes water intoxication. In severe cases, this kind of poisoning causes convulsions and seizures. There are reports of such poisoning in small children and in psychiatric patients. The reason water "changes" from being harmless to being harmful is directly related to the amount of it taken into the body at one time. Drinking "too much" water causes the toxicity. Taking "too much" of a chemical into the body causes toxicity. This relation is true for all chemicals regardless of whether they are natural or man-made.

Toxicity of the Chemical

Toxicity is a measure of the poisoning strength of a chemical. Chemicals that are only weakly toxic require large doses to cause poisoning. Strongly toxic chemicals only need small doses to cause poisoning.*

There is a tendency to think of chemicals in terms of those which are poisonous or toxic and those which are harmless. These categories are used for convenience, but they imply that toxicity or its absence is an all-or-nothing property of a chemical. This is not the case because any chemical can cause poisoning if a sufficient dose of it is taken into the body.

To put it another way, all chemicals can be toxic. It is the amount or dose taken into the body that determines whether or not they will cause poisonous effects. Poisoning, then, is caused not just by exposure to a particular chemical, but by exposure to too much of it.

Removal from the Body

Many workplace chemicals which enter the body are excreted unchanged. Others are broken down. The breakdown products may be more toxic or less toxic than the original chemical which entered.

Other chemicals still are stored temporarily in body organs and are removed over a short period of time. Eventually most chemicals and their breakdown products are removed as waste in the feces, urine, sweat or exhaled breath. A few chemicals such as graphite or silica dusts can be inhaled into the lungs where they lodge for many years and may never be completely removed.

As a general rule there is less risk of chemically caused disease if the body can

- break down the chemical into less toxic products, and/or
- rapidly remove the chemical from the body.

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* Toxicologists often use animal tests to determine whether small or large doses of a particular chemical cause toxicity. One such test measures the dose of a chemical that causes death to 50% of the animals being tested. This test is called the "Lethal Dose 50" (LD_{50}) and is described in detail in the CCOHS document, "What is an LD_{50}?"[2]

Biological Variation

Several characteristics of the exposed person or animal can influence the degree of poisoning which occurs. These include age, sex and individual susceptibility.

3. HOW ARE WE EXPOSED TO AMOUNTS OF CHEMICALS SUFFICIENT TO CAUSE POISONING?

There are two main ways that too much of a chemical can enter the body and cause poisonous effects:[3]

By Sudden Exposures

A one-time exposure to relatively large amounts of the chemical can overwhelm the body. In the workplace this may happen through improper handling of the chemical, or when there is an accidental spill or a leak from a valve or pipe carrying chemicals. It might also happen during maintenance or cleaning of equipment that normally contains chemicals (such as a solvent vat). The ill-health effects caused by one-time, sudden, high exposures are often called "acute toxicity" effects. Some examples of acute toxicity are listed below:

- Inhalation of high concentrations of acid vapours might cause serious burns of the mouth and airways leading to the lungs.
- Skin contact with substantial amounts of certain organic solvents that are absorbed through the skin may cause dizziness and nausea.
- Inhalation of dusts can cause irritation of the respiratory tract, dryness in the throat, and coughing.

By Repeated Exposures Over a Long Period of Time

A repeated exposure over a long period of time can also cause too much chemical to enter the body and produce poisoning. This kind of poisoning occurs because the exposure is repeated day after day over many years. The exposure levels may be too small to cause any acute toxicity. Ill-health effects caused in such situations are often called "chronic toxicity" effects. The following are some examples of chronic toxicity:

- Inhalation of certain acid vapours at concentrations which do not cause acute toxicity may, over long periods of time, cause loss of tooth enamel, eventually leading to extensive tooth decay.
- Inhalation and skin absorption of some organic solvents at concentrations which do not cause acute toxicity may, over long periods of time, cause damage to nerve tissue.

- Repeated exposure to dusts containing quartz can cause scar tissue in the lungs. This leads to severe and permanent lung damage.

4. WHAT ARE ACUTE AND CHRONIC TOXICITY?

Most chemicals can cause both acute and chronic toxicity depending on the conditions of exposure. The adverse health effects caused by the chemical in the two types of toxicity are often quite different. It is not usually possible to predict what the chronic toxicity of a chemical might be by looking at its acute toxicity, or vice versa.

Acute Toxicity

In most cases, much more is known about the acute toxicity of a chemical than its chronic toxicity. The understanding of acute toxicity usually comes from studies with animals exposed to relatively high doses of the substances. Accidental overexposure, spills and emergencies have added to our knowledge of acute toxicity in humans. The health effects may be temporary, such as skin irritation, sickness or nausea, or they may be permanent: blindness, scars from acid burns, mental impairment and so on.

Acute toxicity is often seen within minutes or hours after a sudden, high exposure to a chemical. However, there are a few instances where a one-time high-level exposure causes delayed effects. For example, symptoms of high exposures to certain pesticides may not appear for several days.

Chronic Toxicity

Much of the knowledge we have about chronic toxicity comes from animal experiments. In addition, much has been learned from studying groups of people occupationally exposed to a chemical for many years. As a general rule, chronic toxicity appears many years after exposure first began. The resulting disease occurs only because the exposure has taken place repeatedly over many years. Chronic toxicity diseases do not seem to be caused by sudden one-time exposures. Chronic toxicity is thought to occur in one of two main ways. These can be explained by using sodium fluoride and n-hexane as examples.

- Sodium fluoride, at very low concentrations (such as in toothpaste or drinking water), causes no noticeable adverse health effects, even after years of exposure. Indeed, at these low levels, the effects are considered beneficial for teeth. However, if much higher concentrations of sodium fluoride enter the body repeatedly, they deposit and build up in the bones. At first, the amount of fluoride in the bone may not cause any problems, but after years of repeated high exposure, symptoms of bone disease may appear.

- On the other hand, the chemical n-hexane is not deposited or accumulated in the body. It is broken down in the liver. One of the breakdown products can "attack" nerve cells in the fingers and toes. These kinds of cell are not replaced easily. With continued exposure for many years the damage to the cells increases until a point is reached where symptoms appear in the nerves of the fingers and toes.

One special case of chronic toxicity is cancer. Repeated exposure to some chemicals for long periods of time may cause cancer.

Often people express concern about cancer developing after a one-time exposure to a cancer-causing agent. While there is no absolute proof that cancer will not occur from a one-time exposure, all the evidence indicates that repeated exposure over a long period of time is necessary before cancer develops.

5. WHAT ARE THE DIFFERENCES BETWEEN TOXICITY AND HAZARD?

There is a tendency to believe that if only small amounts of a chemical are needed to cause poisoning, then the chemical is highly hazardous. This is not necessarily so. A highly toxic chemical can have a low health hazard if it is used with proper precautions and care. On the other hand, it is possible that a chemical of low toxicity may present a high health hazard if it is used carelessly or inappropriately. Toxicity is a measure of the poisoning strength and is an unchanging characteristic of a chemical. Hazard is not the same. It is a variable feature of a chemical. Hazard is the likelihood that a chemical will cause poisoning, given its poisoning strength and the amounts and manner in which it is used, stored and handled. The toxicity of a chemical cannot be changed, but the hazard it presents can be controlled and minimized.

6. SUMMARY

- The physical world is made entirely of chemicals.
- No chemical causes poisoning without first coming into contact with the body.
- All chemicals, man-made or natural, can cause poisoning if the amount entering the body is high enough.
- Toxicity is a measure of the poisoning potential of a chemical. The toxicity of a chemical does not change.
- Two types of poisoning can occur--one caused by too much chemical entering the body at one time (acute toxicity), the other by a chemical entering the body too often over a long period of time (chronic toxicity).
- Hazard is the likelihood that a chemical will cause poisoning, taking into account the circumstances of handling and use. Hazard is a variable feature of a chemical.

REFERENCES

1. Halton, D.M. How workplace chemicals enter the body. Hamilton, Ont. : CCOHS, 1985

2. Bello, S.; Halton, D.M. What is an LD_{50}? Hamilton, Ont. : CCOHS, 1985

3. Ottoboni, M.A. The dose makes the poison. Berkeley, Calif. : Vincente Books, 1984